ISSN (Online) : 0974-5645
ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 8(3), 296–300, February 2015*
DOI : 10.17485/ijst/2015/v8i3/59873

Effect of Minimum Quantity Lubrication with Gamma-Al_2O_3 Nanoparticles on Surface Roughness in Milling AISI D3 Steel

Mostafa Hadi* **and Reza Atefi**

Department of Mechanical Engineering, Dehaghan Branch, Islamic Azad University, Dehaghan, Iran;
Mostafahadi1980@yahoo.com, Atefireza@yahoo.com

Abstract

This paper presents an investigation into the Minimum Quantity Lubrication (MQL) and MQL with gamma-Al_2O_3 nanoparticles in end milling processes of AISI D3 steel work material to analyze the effects of cutting parameters on surface roughness with taguchi method. The experimental results show when gamma-Al_2O_3 nanoparticle dispersed to vegetable-oil with volume fraction 1%, the surface roughness decreased about 0.3μm and improved about 15% than pure MQL. Also by dispersing gamma-Al_2O_3 nanoparticle to vegetable oil with volume fraction 2%, surface roughness decreased about 0.5μm and improved about 25% than pure MQL. This results indicate better performance application of gamma-Al_2O_3 nanoparticles when it is dispersed in vegetable oil.

Keywords: Milling, Minimum Quantity Lubrication (MQL), Nanoparticle

1. Introduction

Today many techniques for improving lubricating in machining process are used. One of them is Minimum Quantity of Lubrication (MQL) that vegetable oil mixed with air and spray to machining zone under certain flow rate and pressure air. MQL plays a significant role in manufacturing processes and improved the machining efficiency such as high surface quality, lower tool wear and etc. The other technique is dispersing nanoparticles in fluid. Efforts to disperse nanoparticles possessing high thermal conductivity have been undertaken to enhance thermal properties of these conventional heat transfer fluids[1–5].

Nam et al.[6] investigated the micro-drilling process using nanofluid minimum quantity lubrication the nanofluid. Their experimental results show that the nanofluid MQL increases the number of drilled holes and reduces the drilling torques and thrust forces. In addition, the nanofluid MQL successfully removes remaining chips and burrs to improve the quality of drilled holes.

Shen et al.[7] investigated on the forces and tool abrasion in near dry grinding with dispersing MoS_2, diamond and Al_2O_3 nanoparticles in vegetable oil. Based on their research the maximum decrease of the force in this process happened in the MQL with 100nm diamond nanoparticles with the volume fraction 1.5%.

Vasu et al.[8] studied on the influence of MQL with nano-Al_2O_3 on surface quality of Inconel 600. They founded that with increasing volume fraction of nano-Al_2O_3 in vegetable oil surface quality is increased.

Kang et al.[9] studied the effect of the MQL in high-speed end-milling of AISI D2 steel. They understood that with using MQL can reduce thermal cracks. They found the best condition of MQL to increase tool life.

Experimental results for pure MQL, MQL+1% gamma-Al_2O_3 nanoparticle and MQL+ 2% gamma-Al_2O_3 nanoparticle are designed. This study presents a research of the effect on surface roughness dissipation of suspending gamma-Al_2O_3 nanoparticles in vegetable MQL oil when milling AISI D3 steel at different speed-feed-depths of cut combinations by HSS end mill tools.

**Author for correspondence*

2. Experimental Setup

2.1 Work Piece Material, Machine Tool, Cutting Tool, Cutting Condition and Measurement

AISI D3 steel was selected as a work piece. It is an air hardening, high-carbon, high-chromium tool steel and it has high wear and abrasion resistant properties. Typical applications for AISI D3 Steel: blanking and forming dies, forming rolls, press tools, punches bushes. AISI D3 steel's high chromium content gives it mild corrosion resisting properties in the hardened condition. Dimension of the work piece is 20*20*60 mm. The chemical composition of this material is 0.2% C, 0.61% Mn, 12.1% Cr, 0.3% Ni, 0.6% Si, 0.25%Cu, 1% V, 0.03% P and 0.03% S.

The milling tests were carried out by using a LUNAN, ZZX6350ZA model NC milling machine that is equipped with a maximum spindle speed of 2000 rpm. An 8mm HSS TiN coated end mill (ISO 1641-1-78) was selected as a tool shown in Figure 1.

Spindle speed (N-rpm), feed rate (f-mm/rev) and depth of cut (a-mm) were measured as machining parameters. The values of cutting parameters were chosen from the catalog tool recommended for the tested material.

The MQL in this process should lubricate the cutting zone by nozzle of MQL set. Air pressure is 4 bar and distance of nozzle to cutting zone is 50mm with 22.5 degree angle and the flow of vegetable oil mixed with air is 200 ml/h in this study because optimum lubrication is in this condition. Experimental results are designed for pure MQL, MQL+1% gamma-Al_2O_3 nanoparticle and MQL+ 2% gamma-Al_2O_3 nanoparticle. The purity and size of gamma-Al_2O_3 particle are 99% and 20nm.The experimental set-up is shown in Figure 2.

The surface roughness was measured by using the Diavite-compact model for milling surface in this experiment with centesimal accuracy. Measurements was based on R_a method and the sampling length (L_c=0.8mm), measuring length (L_m=4mm) and traverse length (L_t=5.6mm) are taken, respectively. The photograph of this machine is shown in Figure 3.

2.2 Experimental Design

A total of 27 experiments based on Taguchi's L9 orthogonal array were carried out with three different conditions: pure MQL, MQL+1% gamma-Al_2O_3 particle and MQL+2% gamma-Al_2O_3 nanoparticle therefore 9 experiments done for each condition are designed with Minitab software.

Taguchi used the Signal-to-Noise (S/N) ratio as the quality characteristic of choice. In this study, arithmetic average roughness (R_a) is investigated and the lower the better ratio is selected to achieve minimum roughness and is given below[10].

$$S/N = -\log\left(1/n\sum_{i=1}^{n}(y_i)^2\right) \quad (1)$$

Where; is the average of data observation, n the number of observations and y_i is the observed data.

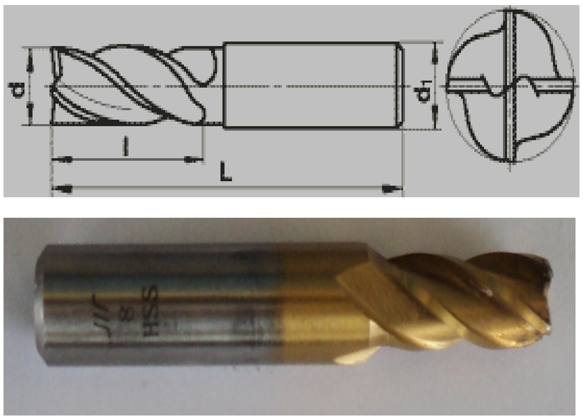

Figure 1. HSS tool (L=69mm, l=19mm, d1=10mm and D=8mm).

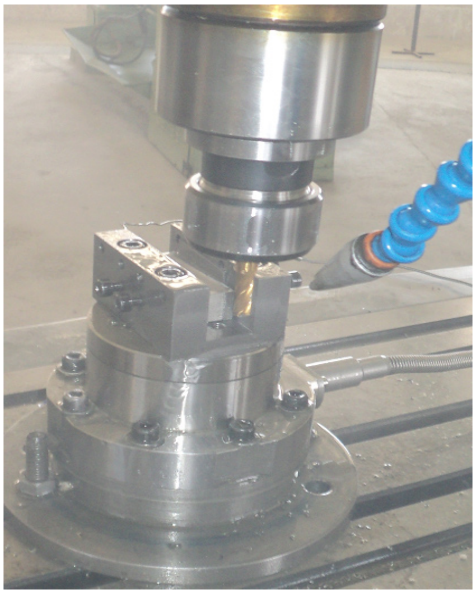

Figure 2. Exprimental set up in milling with MQL.

Figure 3. The measuring surface roughness machine.

The characteristic used in this experiment was the S/N ratio smaller is better, where the low surface roughness is desirable. For each of the 9 trials and the values are given in Table 1.

3. Result and Discussion

Surface roughness plays an important role in the performance of machining. Therefore, measuring and discussing the average surface roughness is utmost important. The average surface Roughness (R_a) on the machined surface was measured perpendicular to the feed marks after every cut. Surface roughness was measured three times and its average value was calculated. The results for 3 conditions were concluded in Table 2.

3.1 Analyses the Results of Experiment

Figure 4 shows the effect of different parameters (Spindle speed (A), Feed rate (B) and Depth of cut(C)) on surface roughness by HSS end mill tool.

The result of Figure 4 for three conditions shows by increasing the speed spindle, surface roughness value is decreased. The results show that 1500rpm speed spindle is the best condition of milling to increase surface quality.

By increasing the feed rate surface roughness is increased. The result show that feed rate of 0.13 mm/rev is the best condition of milling to increase surface quality.

Table 1. Process parameters and their levels

Parametrs	1	2	3
Spindle speed(rpm) A	565	950	1500
Feed rate (mm/rev) B	0.13	0.2	0.36
Depth of cut(mm) C	0.4	0.7	1

Table 2. Results of experiment

No	A	B	C	R_a(μm) Pure MQL	R_a(μm) MQL+1% gamma-Al_2O_3 particle	R_a(μm) MQL+1% gamma-Al_2O_3 particle
1	1	1	1	1.71	1.52	1.48
2	1	2	2	3.08	2.53	2.23
3	1	3	3	2.73	2.44	2.10
4	2	1	2	2.06	2.00	1.88
5	2	2	3	1.71	1.50	1.34
6	2	3	1	1.89	1.66	1.45
7	3	1	3	1.59	1.41	1.31
8	3	2	1	1.78	1.67	1.36
9	3	3	2	1.99	1.66	1.45

By increasing the depth of cut from 0.4 to 0.7 mm, surface roughness is increased. By increasing the depth of cut from 0.7 to 0.1 mm surface roughness is decreased. Depth of cut 0.7mm is the best condition of milling to increase surface quality.

The results show best surface roughness is 1.31μm for MQL+2% gamma-Al_2O_3 nanoparticle when spindle speed 1500rpm, feed rate 0.13 mm/rev and depth of cut 0.7 mm.

3.2 Comparison of Surface Roughness in Case of using Pure MQL, MQL+ MQL+1% Gamma-Al2O3 Nanoparticle and MQL+2% Gamma-Al2O3 Nanoparticle

Effect of MQL+nanoparticles on surface roughness according to different performed experiments has been shown in Figure 5.

Considering diagram 5 and using point to point calculations when gamma-Al_2O_3 nanoparticle dispersed to vegetable-oil with volume fraction 1%, the surface roughness decreased about 0.3μm and improved about 15% than pure MQL. Also by dispersing gamma-Al_2O_3 nanoparticle to vegtable oil with volume fraction 2%, surface roughness decreased about 0.5μm and improved about 25% than pure MQL. This results indicate good performance application of gamma-Al_2O_3 nanoparticles when it is dispersed in vegetable-oil.

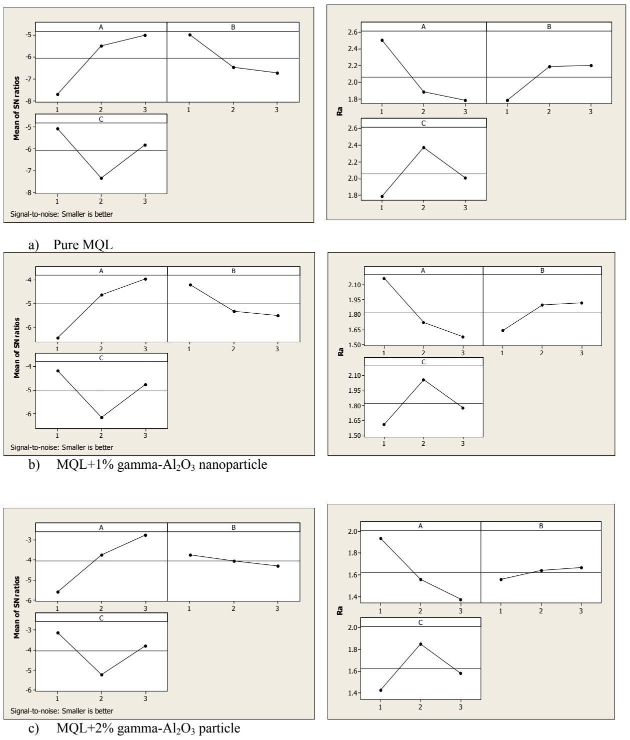

Figure 4. The results for a) pure MQL, b) MQL+1% gamma-Al_2O_3 nanoparticle and c) MQL+2% gamma-Al_2O_3 nanoparticle.

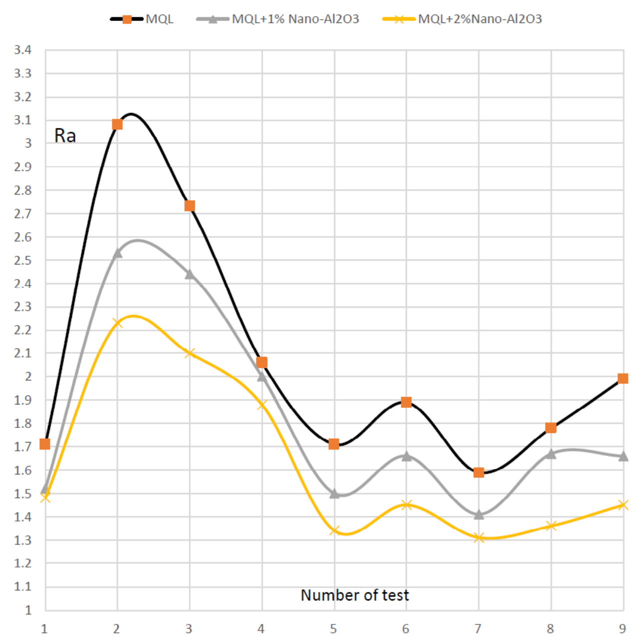

Figure 5. Diagram of surface roughness for pure MQL and MQL+nanoparticles.

4. Conclusions

The following conclusions can be drawn based on the experimental results.

1. By increasing the speed spindle, surface quality is increased for pure MQL, MQL+1% gamma-Al_2O_3 nanoparticle and MQL+2% gamma-Al_2O_3 nanoparticle.
2. By increasing the feed rate surface quality is decreased for three conditions.
3. By increasing the depth of cut from 0.4 to 0.7 mm, surface roughness is increased. By increasing the depth of cut from 0.7 to 0.1 mm surface roughness is decreased.
4. The results show best surface roughness is 1.31μm for MQL+2% gamma-Al_2O_3 nanoparticle when spindle speed 1500rpm, feed rate 0.13 mm/rev and depth of cut 0.7 mm.
5. With using point to point calculations when gamma-Al_2O_3 nanoparticle dispersed to vegetable-oil with volume fraction 1%, the surface roughness decreased about 0.3μm and improved about 15% than pure MQL. Also by dispersing gamma-Al_2O_3 nanoparticle to vegetable oil with volume fraction 2%, surface roughness decreased about 0.5μm and improved about 25% than pure MQL. This results indicate good performance application of gamma-Al_2O_3 nanoparticles when it is dispersed in vegetable oil.

5. Acknowledgement

All experimental data driven from research which is entitled "Investigation on volume fraction of nano-Al_2O_3 in near dry machining" which is registered and performed in Islamic Azad university, Dehaghan branch.

6. References

1. Hadi M. Investigation on turning of AISI H13 with applying minimum quantity of lubricant. Indian journal of science and technology. 2013; 6(2):4094–7.
2. Atefi R. Khajeali M, Rasafchi M. Effect of multi-wall carbon nanotubes with different volume fractions on surface roughness in electro discharge machining. Indian journal of science and technology. 2014; 7(5):648–53.
3. Obikawa T. Machining with Least Quantity Lubrication. Advanced machining technologies. 2014; 11:255–81.

4. Liao YS, Lin HM, Chen YC. Feasibility study of the minimum quantity lubrication in high-speed end milling of NAK80 hardened steel by coated carbide tool. Int J Mach Tool Manufact. 2007; 47:1667–76.
5. Hwang YK, Lee CM. Surface roughness and cutting force prediction in MQL and wet turning process of AISI 1045 using design of experiments. J Mech Sci Tech. 2010; 24(8):1669–77.
6. Nam JS, Lee P-H, Lee SW. Experimental characterization of micro-drilling process using nanofluid minimum quantity lubrication. Int J Mach Tool Manufact. 2011; 51:649–52.
7. Shen B, Shih A, Tung SC. Application of nanofluids in minimum quantity lubrication grinding. Tribol Lubric Tech. 2008; 51:730–7.
8. Vasu V, Reddy GPK. Effect of minimum quantity lubrication with Al2O3 nanoparticles on surface roughness, tool wear and temperature dissipation in machining Inconel 600 alloy. Journal of Nanoengineering and Nanosystems. 2011; 225(1):3–16.
9. Kang MC, Kim KH, Shin SH, Jang SH, Park JH, Kim C. Effect of the minimum quantity lubrication in high-speed end-milling of AISI D2 cold-worked die steel (62 HRC) by coated carbide tools. Surf Coating Tech. 2008; 202(22):5621–4.
10. Mathew B, Babu J. Multiple Process Parameter Optimization of WEDM on AISI304 Using Taguchi Grey Relational Analysis. Procedia Materials Science. 2014; 5:1613–22.